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(54) **VACUUM INSULATED VENTURI METER FOR AN EXHAUST GAS RECIRCULATION APPARATUS**

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F02D 41/00	(2006.01)

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CPC ***G01F 1/44*** (2013.01); ***F02D 21/08*** (2013.01); ***F02M 26/47*** (2016.02); ***G01F 1/40*** (2013.01); *F02D 2041/0075* (2013.01); *F02M 26/05* (2016.02); *F02M 26/23* (2016.02)

(58) **Field of Classification Search**

CPC G01F 1/44; G01F 1/40; F02M 26/47
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(56) **References Cited**

U.S. PATENT DOCUMENTS

1,266,428	A	5/1918	Dodge	
2,284,013	A	5/1942	Pardoe	
2,607,743	A *	8/1952	Hession, Jr.	B01F 3/04007 422/276
2,747,976	A	5/1956	Houdry	
3,457,723	A	7/1969	Kerns	
4,147,031	A	4/1979	Tanuma et al.	
4,481,828	A	11/1984	Cheng	
4,651,572	A *	3/1987	Albertz	G01F 1/44 73/706
4,730,500	A *	3/1988	Hughes	A61M 15/00 73/861.22
D296,530	S *	7/1988	Nowacki	B01F 3/04007 D10/96

(Continued)

FOREIGN PATENT DOCUMENTS

GB	1488812 A	10/1977
JP	H11311396 A	11/1999
JP	2008255853 A	10/2008

OTHER PUBLICATIONS

Office Action dated Feb. 2, 2016 of corresponding Japan application No. 2015-527430 translated.

(Continued)

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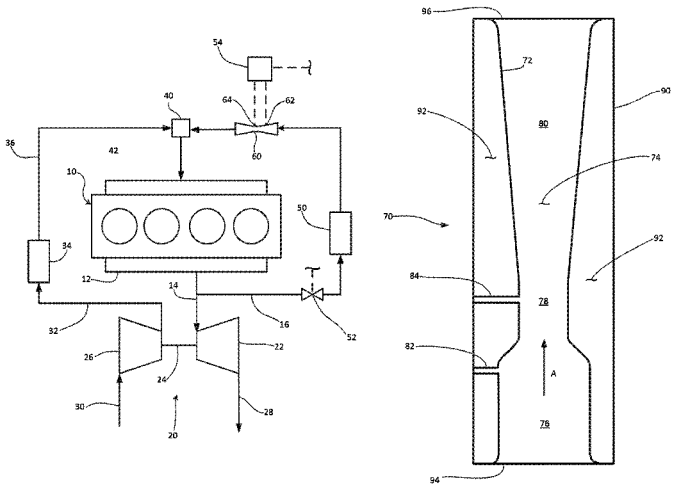
(57) **ABSTRACT**

A venturi flow meter for an EGR apparatus includes an inner wall defining an interior space including a converging inlet section, a throat section, and a diverging outlet section and an outer wall surrounding the inner wall and attached to the inner wall, the outer wall being spaced from the inner wall to define an insulating space between the inner wall and the outer wall.

6 Claims, 2 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

RE33,909	E *	5/1992	Brenner	G01N 25/60 366/17
5,127,173	A *	7/1992	Thurston	G01F 1/3227 73/202
6,058,787	A *	5/2000	Hughes	G01F 1/32 73/861.52
6,408,833	B1	6/2002	Faletti	
6,732,524	B2	5/2004	Sponton	
6,742,335	B2	6/2004	Beck et al.	
7,195,006	B2	3/2007	Khair et al.	
7,469,181	B2	12/2008	Duffy et al.	
7,610,818	B2 *	11/2009	Sanders	G01F 1/44 73/861.63
7,921,830	B2	4/2011	Schneider et al.	
2003/0234009	A1 *	12/2003	Kennedy	F02B 29/0418 123/568.12
2004/0007220	A1	1/2004	Sponton	
2010/0154758	A1	6/2010	Schneider et al.	
2013/0298882	A1	11/2013	Stabnik et al.	

OTHER PUBLICATIONS

International Search Report and Written Opinion of PCT/US2012/050709 dated Oct. 26, 2012.

International Preliminary Report on Patentability of PCT/US2012/050709 dated Jul. 30, 2014.

Extended European search report dated Apr. 22, 2016 of corresponding European application No. 12882940.5.

* cited by examiner

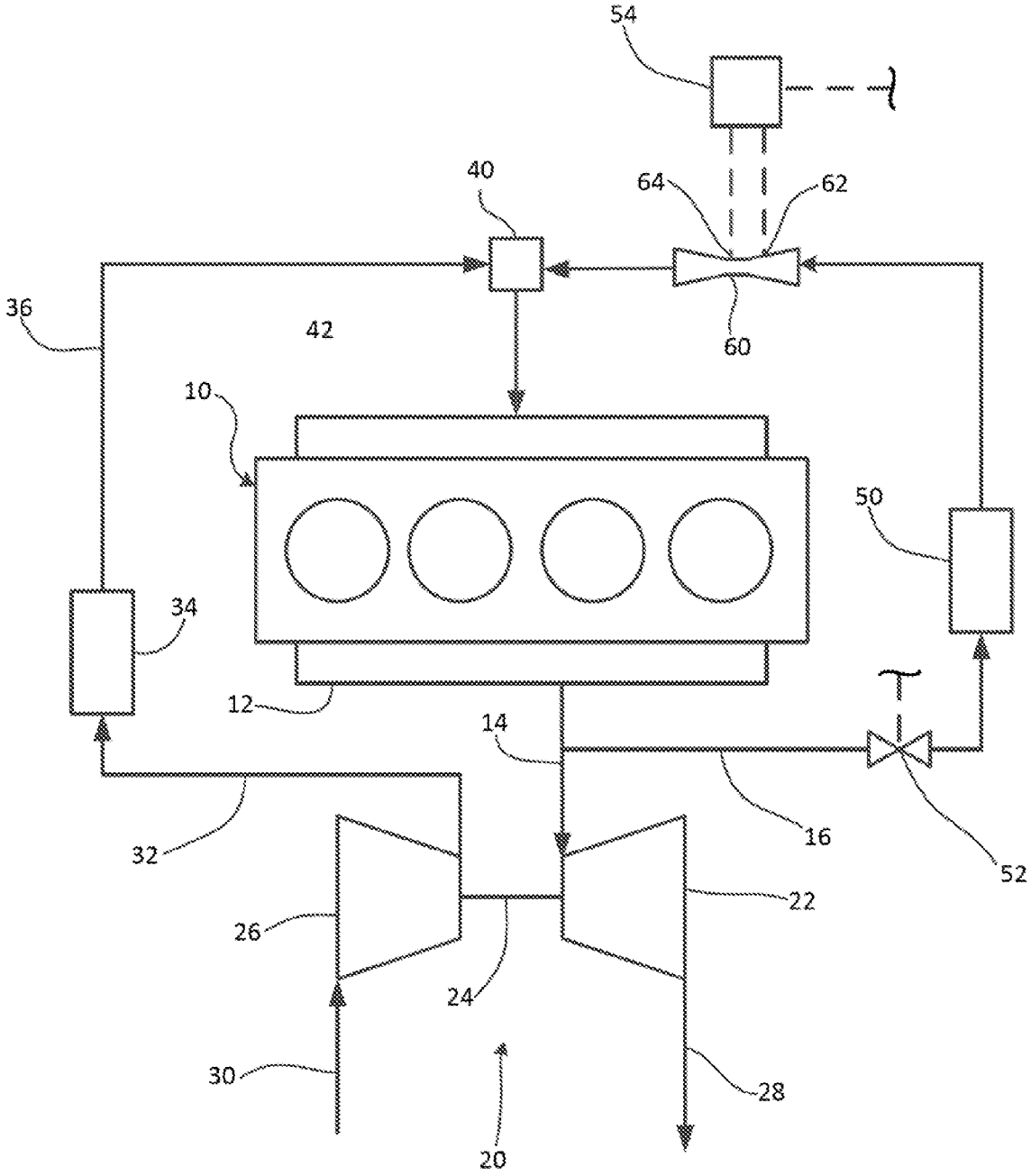


Fig. 1

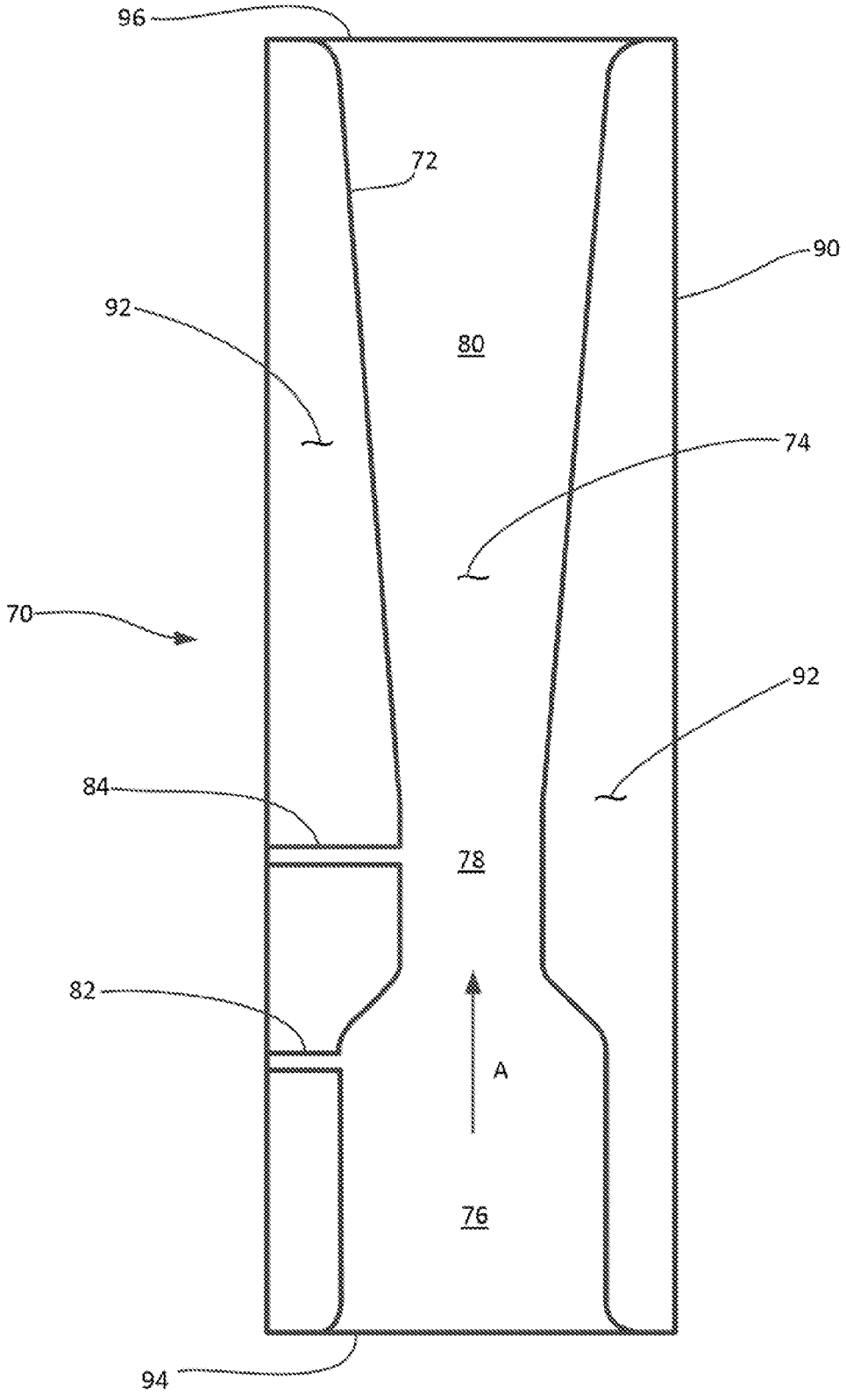


Fig. 2

VACUUM INSULATED VENTURI METER FOR AN EXHAUST GAS RECIRCULATION APPARATUS

FIELD OF THE INVENTION

The invention is directed to exhaust gas recirculation (EGR) apparatuses for internal combustion engines, and more particularly, to a vacuum insulated venturi metering device for an EGR apparatus.

BACKGROUND AND SUMMARY

In internal combustion engines, EGR systems recirculate engine exhaust gas to the engine intake as a method for reducing production of oxides of nitrogen (NOx). The addition of exhaust gas to the intake air reduces the oxygen content of the intake air. This results in lower combustion temperature, and because NOx production is temperature sensitive, lower production of NOx.

Some systems use cooled EGR, that is, exhaust gas that is passed through a heat exchanger. The temperature of cooled EGR gas can get close to the dew point. Further cooling, for example by contact with cooler components, can create significant amounts of condensation. EGR condensation includes soot and other undesirable constituents which can foul EGR components. One such component subject to fouling is a venturi device used to meter the EGR gas.

Conventional solutions to the problem of EGR condensation in a venturi include a system to supply engine coolant as a heat source to maintain a temperature of the venturi walls, which adds expense and complication. Other solutions include a glass fiber insulation wrap around the venturi, which is subject to wear and tear and which requires additional assembly steps.

The invention provides a device for insulating an EGR venturi meter. According to the invention, a venturi meter includes a vacuum space surrounding the venturi body to provide thermal insulation.

A venturi meter according to the invention includes a venturi body having an inner wall defining an inlet end, a throat, and an outlet end. An outer wall surrounds the inner wall and is spaced from the inner wall to provide an insulating space between the outer wall and the inner wall. The outer wall and inner wall are joined to form a seal to prevent air from entering or leaving the insulating space.

According to a preferred embodiment, the insulating space is evacuated to provide a vacuum insulated spaced surrounding the inner wall.

According to an alternative embodiment, the insulating space contains air or another gas having low thermal conductivity.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood with reference to the appended drawings, in which:

FIG. **1** is a schematic of an internal combustion engine and exhaust apparatus, including an exhaust gas recirculation system; and,

FIG. **2** is a longitudinal section view of a venturi flow meter in accordance with the invention.

DETAILED DESCRIPTION

FIG. **1** shows a simplified schematic of an internal combustion engine **10**. Engine exhaust is guided through an exhaust manifold **12** to an exhaust conduit **14**. A portion of the exhaust gas is recirculated to the engine intake through an exhaust gas recirculation (EGR) conduit **16**, which is further described below. The remainder of the exhaust gas is directed to an exhaust gas turbine **22** of a turbocharger **20**. The exhaust gas flowing through the turbine **22** drives the turbine wheel (not shown) and shaft **24**, which drives the compressor **26** of the turbocharger **20**. From the turbine, the exhaust gas is released to the environment through a pipe **28**, typically after passing through some aftertreatment systems (not shown). The compressor **26** draws ambient air through intake conduit **30**, compresses the ambient air to form charge air. The charge air is guided through conduit **32** to a charge air cooler **34**. Cooled charge air is guided through a conduit **36** to a mixer **40**, where the cooled charge air mixes with recirculated exhaust gas. The mixture is then directed to the engine intake manifold **42**.

Recirculated exhaust gas in conduit **16** is carried through and EGR valve **52** to an EGR cooler **50**. The EGR valve **52** is operated by a controller **54** to control the amount of exhaust gas recirculated to the engine air intake, according to engine demand and NOx control requirements. The exhaust gas from the EGR valve **52** flows through a venturi metering device **60**, which measures the quantity of exhaust gas flowing to the engine intake. The controller **54** is connected to receive a pressure signal from a differential pressure sensor installed in sensing communication with ports (see, FIG. **2**) at the venturi metering device's inlet portion **62** and throat portion **64**. Alternatively, individual pressure sensors may be provided in each of the venturi ports. A pressure differential between the inlet portion **62** and the throat portion **64** is used by the controller **54** to calculate mass flow through the venturi metering device **60**. The controller **54** is configured to use the mass flow calculation in controlling the EGR valve **52**.

The exhaust gas flows from the venturi metering device **60** to the mixer **40** to mix with charge air for the engine intake manifold **42**.

EGR gas contains water vapor, soot, and other contaminants. A problem with cooled EGR arises from the gas temperature being brought near the dew point. Further cooling can result in condensation and deposition of water and solid contaminants in the EGR system. This can be a problem in venturi metering devices if condensation fouls the pressure sensor ports.

Turning to FIG. **2**, a venturi metering device **70** according to the invention is illustrated in a longitudinal section view. The venturi **70** includes an inner wall **72** defining an interior space **74** including an inlet portion **76** having a cylindrical entry and a frustoconical transition section that converges in a flow direction (indicated by arrow A) to a throat section **78** at the narrowest part of the interior space **74**. The interior space **74** then widens with the inner wall **72** diverging in a frustoconical outlet section **80**.

A first port **82** is provided in the inner wall **72** at the inlet section **72**. A second port **84** is provided in the inner wall **72** at the throat section **78**. The first port **82** and second port **84** are passages formed to be in fluid communication with the interior space **74** to provide access for communication with a pressure sensor or sensors (not illustrated).

An outer wall **90** surrounds the inner wall **72** and is spaced outwardly from the inner wall to provide an insulating space **92** between the inner wall and the outer wall. In the illustrated example, the venturi **70** has a circular cross-section and the outer wall **90** is spaced radially outward of the inner wall **72** to define an annular space around the inner wall. The outer wall **90** and the inner wall **72** are joined at

the inlet end **94** and outlet end **96** in a way that forms an airtight seal and supports the inner wall and outer wall in spaced relation. The inner wall **72** and outer wall **90** may be joined by welding or other suitable method. Joining the inner wall **72** and outer wall **90** at the ends **94**, **96**, provides that the insulating space **92** extends from the inlet end **94** to the outlet end **96**. According to a preferred embodiment of the invention, the insulating space **92** is evacuated to provide a vacuum insulating space. Alternatively, the insulating space **92** may contain air or another gas.

The inner wall **72** and outer wall **90** may be formed of a metal, such as stainless steel. However, any material capable of being shaped and joined to form a seal, as described here may be used.

The invention has been described in terms meant to be illustrative rather than limiting. Those skilled in the art will understand that the invention is defined by the appended claims.

What is claimed is:

1. A Venturi flow meter in a cooled EGR apparatus, comprising:

an exhaust gas recirculation conduit connectable to an exhaust conduit of an internal combustion engine;

an EGR cooler connected in the exhaust gas recirculation conduit; and,

a Venturi flow meter connected in the exhaust gas recirculation conduit to receive exhaust gas from the EGR cooler, wherein, the Venturi flow meter comprises:

an inner wall defining an interior space including a converging inlet section, a throat section, and a diverging outlet section; and,

an outer wall surrounding the inner wall and attached to the inner wall, the outer wall being spaced from the inner wall to define an insulating space between the inner wall and the outer wall, wherein the inner and outer walls are sealed and the insulating space is evacuated.

2. The Venturi flow meter as claimed in claim **1**, comprising a first pressure sensing port in fluid communication with the interior space at the inlet section and a second pressure sensing port in fluid communication with the throat section.

3. An internal combustion engine exhaust apparatus, comprising:

an exhaust conduit connectable to an engine exhaust manifold;

an exhaust gas recirculation conduit connected to the exhaust conduit;

a valve on the exhaust gas recirculation conduit for controlling flow of exhaust gas through the exhaust gas recirculation conduit;

an exhaust gas recirculation cooler connected on the exhaust gas recirculation conduit to cool exhaust gas for recirculation to the engine; and,

a Venturi flow meter connected on the exhaust gas recirculation conduit to receive cooled exhaust gas from the exhaust gas recirculation cooler, the Venturi flow meter including an inner wall defining an interior space including a converging inlet section, a throat section, and a diverging outlet section and an outer wall surrounding the inner wall and attached to the inner wall, the outer wall being spaced from the inner wall to define an insulating space between the inner wall and the outer wall, wherein the insulating space is evacuated.

4. The internal combustion engine exhaust apparatus of claim **3**, wherein the Venturi flow meter includes pressure sensing means mounted in fluid communication with the interior space at the inlet section and in fluid communication with the interior space at the throat section.

5. The internal combustion engine exhaust apparatus of claim **4**, further comprising a controller operatively connected to the valve to control opening and closing of the valve, and connected to receive pressure signals from the pressure sensing means, the controller being configured to calculate exhaust gas mass flow rate through the Venturi flow meter from the pressure signals and responsive thereto to operate the valve.

6. A Venturi flow meter in a cooled EGR apparatus, comprising:

an exhaust gas recirculation conduit connectable to an exhaust conduit of an internal combustion engine;

an EGR cooler connected in the exhaust gas recirculation conduit; and,

a Venturi flow meter connected in the exhaust gas recirculation conduit to receive exhaust gas from the EGR cooler, wherein, the Venturi flow meter comprises:

an inner wall defining an interior space including a converging inlet section, a throat section, and a diverging outlet section; and,

an outer wall surrounding the inner wall and attached to the inner wall, the outer wall being spaced from the inner wall to define an insulating space between the inner wall and the outer wall, wherein the inner and outer walls are sealed and the insulating space contains air.

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